EXHIBIT A
PART 1 OF 3

Exponent®

Mechanics and Materials Practice

Metallurgical Examination of Soldered Pipe Joints

Metallurgical Examination of Soldered Pipe Joints

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Executive Summary

Exponent analyzed two pipe joints recovered from the Marino carriage house fire that occurred on December 20, 2002. Both pipe joints were soldered at some point prior to the fire, but were found separated under the kitchen sink after the fire. The purpose of the analysis conducted by Exponent was to determine when these two soldered joints were separated.

Exponent analyzed the subject joints by optical microscopy and scanning electron microscopy (SEM) coupled with energy dispersive spectroscopy (EDS). The following results have been obtained from the analyses performed on these joints:

1. Both joints were comprised of a copper tube soldered to a brass fitting.
2. The solder was a lead-free, tin-based alloy with a small amount of copper.
3. The brass fittings were composed of a "free-machining" or leaded-brass.
4. A thick deposit of solder was present on the copper tubes, whereas significantly less solder residue was found on the corresponding brass fittings.
5. Lead was detected in the solder deposit on the outer surface of the copper tubes and the inner surface of the brass fittings.
6. A ridge of solder on one of the copper tubes showed no evidence of melting.

Based upon the results from these analyses, and general observations of the joints, Exponent has formed the following opinions with regards to the separation of these joints:

1. At the time the fire began, all joints of the water piping were intact.
2. The heat from the fire was sufficient to melt the solder at the copper/brass interface, but not the copper/copper soldered joints.

3. Pressure within water line provided the force necessary to separate joint between the copper tube and the brass valve when the solder melted.

4. The separation of the joint between the copper tube and the brass compression fitting followed. Either the weight of the brass valve/copper tube assembly or the movement of components during the fire could have provided sufficient force to separate this joint once the solder melted.

Details of the testing and results that these opinions are based on are contained in the following sections of this report. If additional information becomes available or additional analysis is performed, I reserve the right to revise these opinions.

Introduction

On December 20, 2002, a fire damaged the carriage house owned by Mr. Marino in Dedham, Massachusetts. The kitchen was among the rooms in the carriage house that incurred damage from the fire. The support structure surrounding the kitchen sink was weakened by the fire damage and resulted in the collapse of the sink. Upon investigation of the kitchen area, the sink was removed and water piping under the sink was inspected. One segment of piping from the cold water supply line was found separated from the other piping. This segment consisted of a brass valve soldered to a section of copper tubing, and is shown in Figure 1. The original location and orientation of this segment under the sink is shown in Figure 2.

The separated female portion of the brass valve shown in Figure 1 was originally soldered to the vertical section of copper tubing shown in Figure 3, and the copper tube was soldered to the brass compression fitting shown in Figure 4. The brass compression fitting was threaded onto a plastic-lined, flexible, braided stainless steel hose. This braided hose can also be seen in Figure 4.

It is readily apparent that, in order for the segment of piping shown in Figure 1 to become completely decoupled from the cold water supply line, two soldered joints had to be separated. It is also apparent that two conditions must be met to separate a soldered joint. First, the joint must be heated to a temperature sufficient to melt the solder. Second, a force must be applied to the joint to parallel to the pipe axis such that the opposing joint sections are pulled away from each other while the solder is molten. In this investigation, Exponent analyzed the joint sections shown in Figure 1, Figure 3 and Figure 4 to determine the point in time when these two conditions were met, leading to the separation of these joints.

Figure 1. Photograph of the detached valve and connected copper tube. A photograph of the corresponding male fitting is shown in Figure 3 and the corresponding female fitting is shown in Figure 4.

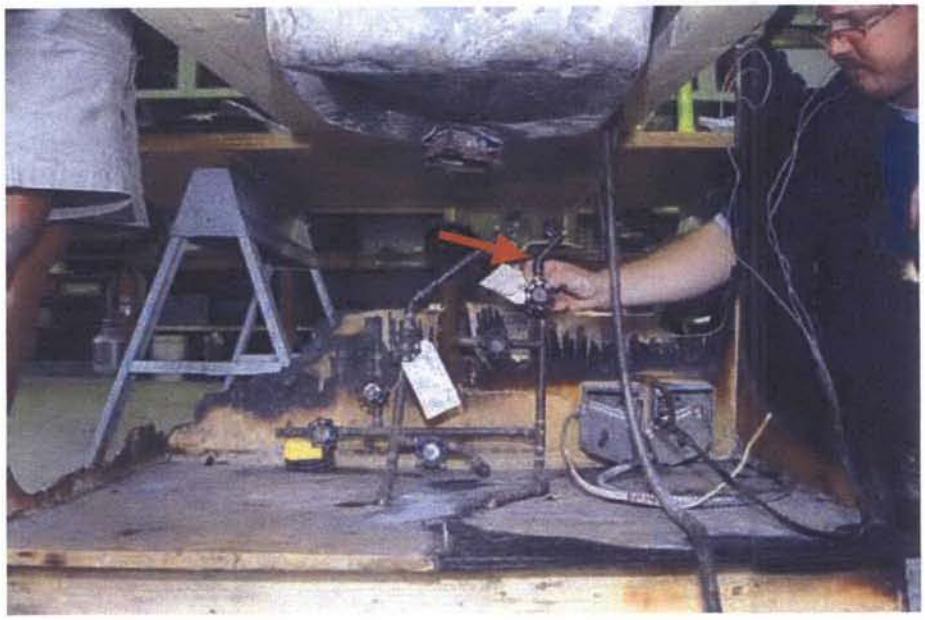

Figure 2. Photograph showing the area under the kitchen sink where the detached valve and connected copper tube would have been located prior to the fire. The red arrow denotes the separated brass valve/copper tube assembly shown in Figure 1.

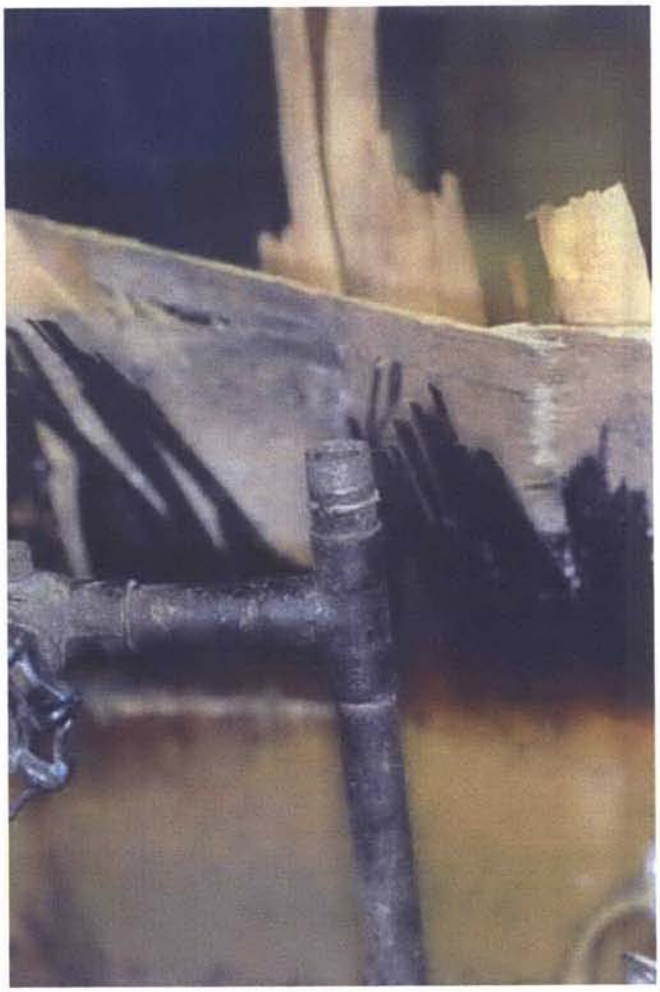

Figure 3. End of copper tubing that was soldered to the brass valve shown in Figure 1.

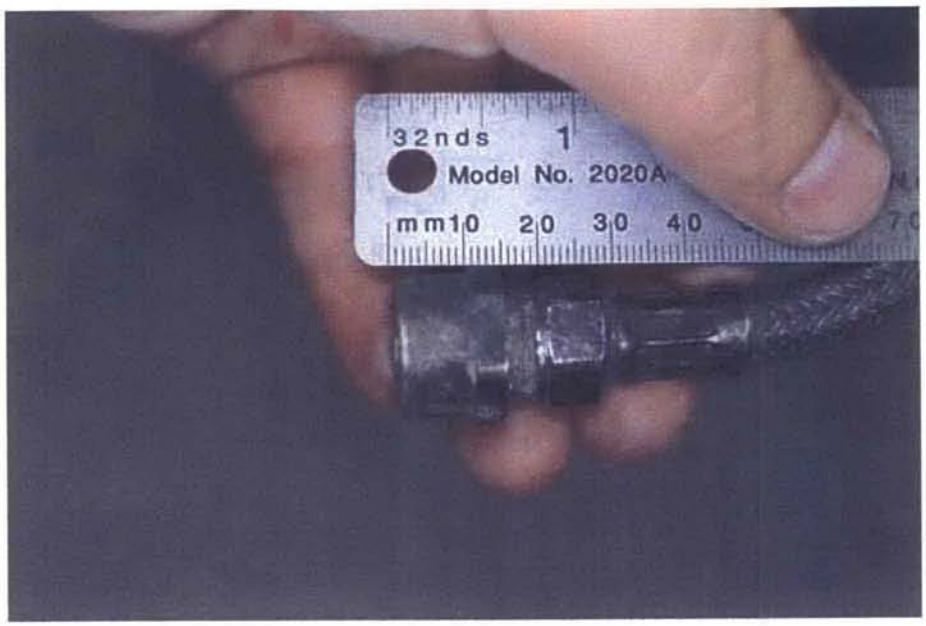

Figure 4. Photograph of the brass fitting that was soldered onto the exposed copper tubing in Figure 1.

Analysis and Results

The four separated pipe joint sections that were examined in this investigation are shown in Figure 5 through Figure 8. Each separated joint was inspected by stereomicroscopy techniques, followed by scanning electron microscopy (SEM) and finally metallography and optical microscopy. The protocol that was followed for preparing and inspecting each of these joints was:

1. Stereomicroscopy of as-received joint;
2. First cut using a water-cooled band saw, as shown in Figure 5 through Figure 8;
3. Perform SEM analysis on the OD (Outer Diameter) of the removed joint;
4. Second cut using a water-cooled band saw, as shown in Figure 5 through Figure 8;
5. SEM analysis on the ID (Inner Diameter) of the removed joint;
6. Metallographic preparation of one half of each joint: mount in epoxy molding compound and polish through 0.25 μm polishing media;
7. Optical microscopy on the polished specimens;
8. SEM on selected polished specimens;

The preparation and analysis was performed at laboratories of Massachusetts Materials Research on January 16, 17 and 18 of 2006. It should also be noted that all samples analyzed by SEM on January 17 and 18 were rinsed with de-ionized water to remove any water-soluble contamination from the surface.

The results obtained from these analyses are presented in detail in the following sections of this report.

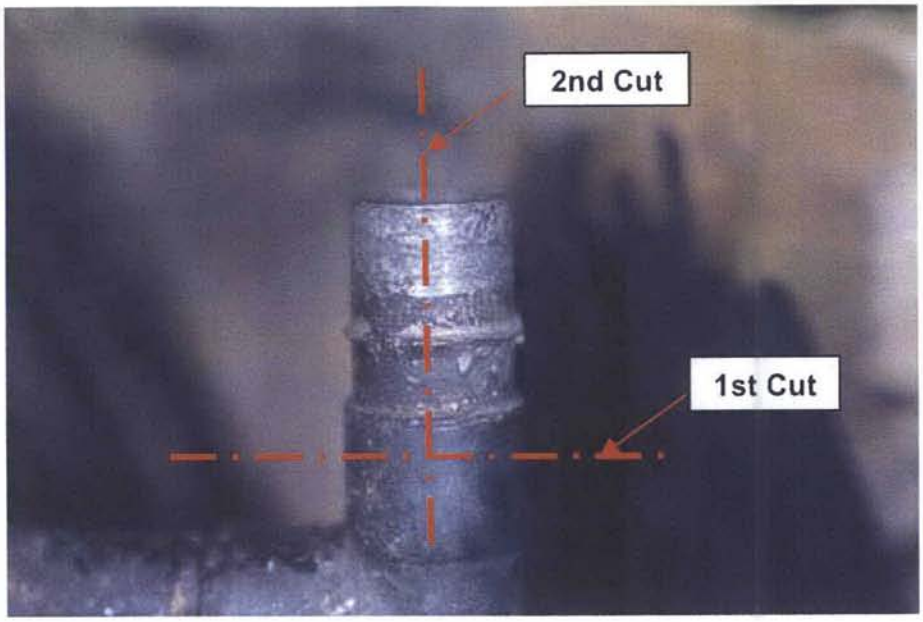

Figure 5. Male joint component that mated to the female joint shown in Figure 6. The red lines indicate where the joint was cut for analysis. This joint section is referred to as "Joint Section 1" in this report.

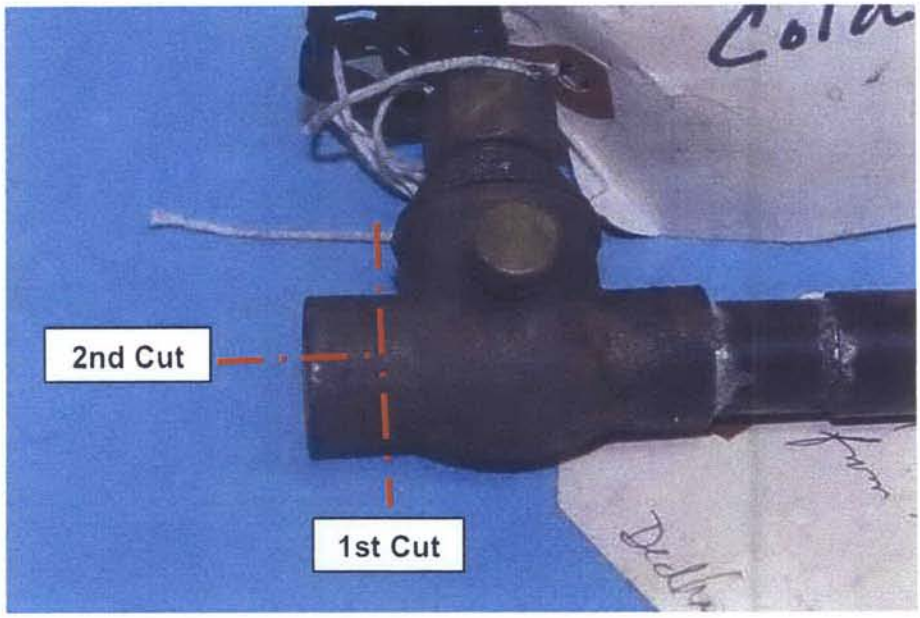

Figure 6. Female joint component that mated to the male joint shown in Figure 5. The red lines indicate where the joint was cut for analysis. This joint section is referred to as "Joint Section 2" in this report.

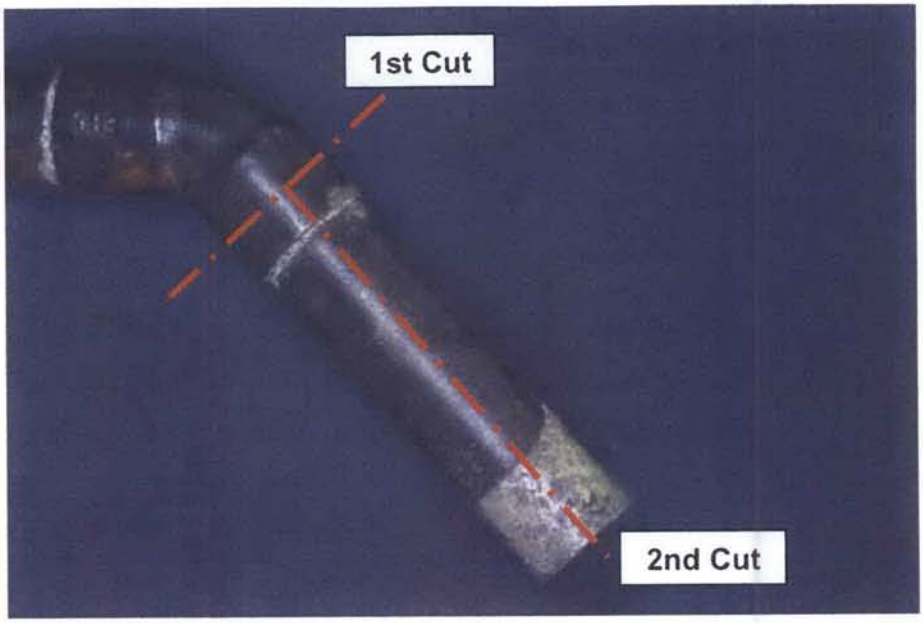

Figure 7. Male joint component that mated to the female joint shown in Figure 8. The red lines indicate where the joint was cut for analysis. This joint section is referred to as "Joint Section 3" in this report.

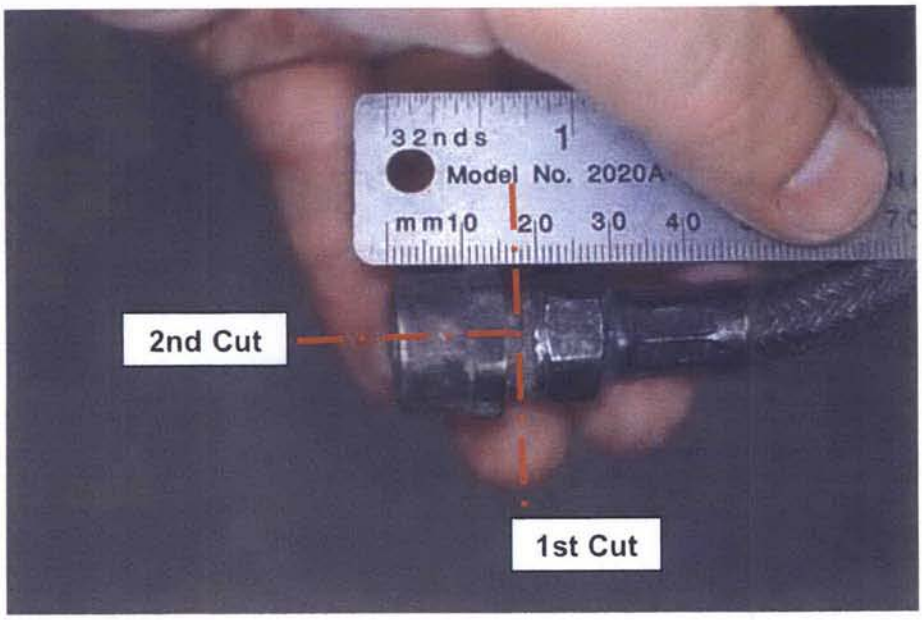

Figure 8. Female joint component that mated to the male joint shown in Figure 7. The red lines indicate where the joint was cut for analysis. This joint section is referred to as "Joint Section 4" in this report.

Joint Section 1

Joint Section 1 is the portion of copper tubing that was soldered to the female brass valve fitting. A stereomicroscope image of Joint Section 1 is shown in Figure 9. The prominent feature on this section of copper tubing is the ridge that circumnavigates the tube. This ridge is shown at a higher magnification in the SEM image in Figure 10. EDS analysis was performed in the regions denoted by the red boxes labeled "1" and "2" in this image. The spectra acquired from this analysis are shown in Figure 11 and Figure 12. The likely source of the carbon peaks in these spectra is soot or other carbonaceous material deposited during or after the fire. The source of the oxygen peaks is likely metal oxides. The primary metallic elements present in these regions are tin and copper, which indicates that this ridge is composed of solder.

The conversations with the plumber who initially installed this pipe indicated that he typically used Canfield "100% Watersafe" or similar brand solder. According the manufacturer's MSDS, the composition of this solder is 95% tin, 4% copper and 1% silver, by weight. While both tin and copper are present in the spectra in Figure 11 and Figure 12, silver is not detected. Unfortunately, the most intense silver peak has an energy of 2.98 eV, which overlaps with one of the low intensity tin peaks. The approximate location of the silver peak is indicated in both spectra. As a result of this peak overlap, and the relatively small amount of silver in this alloy, EDS cannot confirm the presence of silver in this solder. The presence of the lead peak in Figure 12 is interesting because "100% Watersafe" and other plumbing solders are lead-free alloys; therefore, the lead must come from another source.

This section of copper tubing was cut parallel to the axis of the tube and metallographically prepared so that the cross-section of the copper/solder interface could be investigated. A stereomicroscope image of this cross-section is shown in Figure 13. The ridge of solder can be clearly seen on both sides of the cross-section. This ridge is shown at a higher magnification in Figure 14. It is very interesting to note that the ridge of solder appears to have retained its original shape and still comes to a rather sharp point. The shape of this solder ridge indicates that the solder was not molten when joint was separated. If this ridge of solder had melted, then surface tension would have cause the ridge to lose its original shape in order to reduce its surface area.